

could do would be to formulate a series of experiments which would clear up all debatable points. Arrangements might also be made to enable the work to be carried on immediately after these experiments were completed, the general features of the instrumental equipment to be contingent upon the result of the experiments. If it be possible for me to take advantage of the kind invitation of the French Astronomers, this is the view which I propose to put forward at the Congress.

Remarks on some of the present Aspects of Celestial Photography.

By Professor C. Pritchard, D.D., F.R.S.

When a new science, or a new application of an old one, is in the early stages of its development, as is now the case with stellar photography, any practical remarks connected with its history and progress will certainly possess a peculiar interest when, in the distant future, the art shall have been brought to comparative perfection. It is under this view that I venture to occupy for a few minutes the attention of the Society.

We are greatly indebted to General Tennant for his recent contribution to our theoretical knowledge of the nature and position of the foci of cylindrical pencils of light incident on parabolic mirrors, when the axes of these pencils are inclined to each other at considerable angles. By considerable angles I mean such as extend through one to three, or even four, degrees. These investigations have a very close and important bearing on questions relating to the angular extent of the photographic pictures of the heavens, which may be hoped for through the instrumentality of reflecting telescopes. One result which I gather from General Tennant's labour is that, even at angles slightly exceeding one degree from the axis of the mirror, discernible astigmatism and distortion may be expected to commence; and if such be found to be the actual result in practice, then photographic pictures of the distribution of stars will be necessarily confined within very narrow limits indeed; and if the whole heavens are to be photographically charted, then the number of the plates will become unavoidably enormous, inasmuch as no single plate could be expected to contain more than five or six square degrees, in at all events such perfection as not to offend the eye, and remind it forcibly and continuously of the comparative imperfection of the means adopted for the formation of the pictures. Passing for a moment from these inauspicious expectations of aid from telescopic mirrors, I find from a recent printed note of Mr. Common that the photographic results, at present derived from specially constructed object-glasses, are, in respect of accuracy of form and extent of available field, not much more hopeful than those predicted by mathematical in-

vestigation in the case of reflectors. Mr. Common, speaking of the really beautiful results obtained by MM. Henry, says: "Looking now at a picture of one of the faintest stars on the plate, and about the centre of the field, these images are quite distinct and perfectly symmetrical; it is only when we get about 1° from the centre that distortion begins. . . . We must therefore consider that the field of this instrument is a circle of about 2° diameter . . ."

It was with a view of ascertaining, in respect of circularity of the stellar images and available extent of the field, *within the limits of agreeable representation*, that I recently commenced some experiments with the De la Rue reflecting telescope of 13 inches aperture. The ordinary plate-holder of this instrument is a circle of two inches only in diameter, at a focal distance of 120 inches, and consequently it comprehends a field scarcely exceeding a single degree in diameter. Beautifully perfect as this field is, and presenting images of the fainter stars admitting of refined measurements, suitable even for the purposes of stellar parallax, it affords no adequate extent of picture practically adapted for the larger scheme of charting the heavens. I accordingly caused to be constructed a camera of more than double this diameter, and affording a circular field extending to about $2^\circ.7$; and although its construction with home resources was very rough and temporary in its character, nevertheless a series of negatives was obtained exhibiting not the slightest discernible deformity in the figures of the stars. This encourages me to hope that the field may be safely extended yet further with suitable appliances, and possibly sufficiently so for efficient and general charting. One of these negatives thus considerably passing the angular limits indicated by the mathematical analysis, I have very recently submitted to the judgment of some members of the committee delegated by the Society to inquire into such matters.

Independently of this, at a meeting of the Photographic Committee of the Royal Society, comprising several of the members of the former body, it was proposed that experiments should be made with two mirrors of widely different focal lengths in order to determine what is the greatest extent of available field to which photographic pictures can be thereby carried. Mr. De la Rue, with his well-known and thoughtful generosity, undertook to provide two such mirrors for the determination of the question, and he has placed them in my hands at Oxford with the view of mounting them temporarily on the solid frame of his reflector in the University Observatory. The aperture of each is 15 inches, with focal lengths respectively of 80 inches and 120 inches. Cameras are now in process of construction capable of photographing fields of $3^\circ 20'$, and extending to nearly 5° in diameter. What the result may be cannot be told until after the inquiry has been completed.

There is also another question of some importance to be

decided. It relates to the conical or trumpet-shaped form of the telescope tube, indicated in General Tennant's paper already referred to. There can be no doubt that owing to the ordinary cylindrical form of the tube very much light from stars whose images are formed near the edge of the field is cut off from incidence on the mirror. This fact will also necessarily interfere with the correct estimation of the magnitude of such stars. On the other hand, it is indicated in the analysis referred to that there is much probability of astigmatism and distortion in the images of these widely angular pencils, and it may even turn out that deformation is partially prevented by the mouth of the ordinary cylindrical tube; for it is one of the results of the mathematical investigation that a diaphragm placed within the tube may conduce in some degree to the flatness of the field. All this is a subject for further practical inquiry, and, as Mr. Common reminds us by a forcible remark, "there is not (at present) much information available, and what there is is such as rather raises than removes doubts."

Should it so happen that considerably wider fields than those indicated by the mathematical analysis can be successfully pictured on the plates, this need not be regarded as contravening the correct interpretation of General Tennant's research. For the photographic images are not in any sense mathematical points; and as to their physical genesis, we are greatly in the dark. One thing is certain, that they grow under continuous exposure; but whether that growth is due to the diffusion of the light, or in some degree to the unsteadiness of the atmosphere or of the instrument, or to some molecular action, extending as it were from a centre of disturbance, who can at present tell?

One conclusion, I think, is clearly deducible from the foregoing remarks, to the effect that the method and final plan of a general charting of the heavens is not yet wholly ripe for decision. For my own part, I do not think it a chimerical hope that before long it may be within the power of a single observatory, provided with two, or it may be three, capable assistants, to procure a series of charts of the heavens, extending from the Pole to the Equator, photographed on an efficient scale, without unpleasant distortion, extending to stars nearly as faint as the fifteenth magnitude, and reproduced in a permanent form nearly to the fourteenth, and then circulated among astronomers within a space of time not exceeding four years. The plates, however, must necessarily be duplicated by a second instrument for the purposes of rectification.

These, however, are questions which await discussion at the approaching Conference at Paris. Meanwhile there are two mottoes applicable to the present condition of the matter before us. The one is "*Forwards!*" and the other is "*Festina Lente.*"

1887, April 5.

On the Variations of Level and Azimuth of the Transit Circle at the Royal Observatory, Greenwich. By H. H. Turner, M.A., B.Sc.

In Vol. XXIX. of the *Memoirs* of the Royal Astronomical Society, Mr. William Ellis has given a very complete account of the changes of level and azimuth errors of the Transit Circle during the early years of its history (1851-1858). He found that there were fluctuations in the position of the instrument in both these elements which followed very closely the changes of external temperature, especially those of long period, such as the annual variation. As the changes of position of an instrument which has been in constant use for so long a period are of interest, the following tables have been recently formed, showing the simple arithmetical mean of the adopted level errors in each month, and of the adopted azimuth errors in each month, for the period 1851-1884. From the means for each month that for the year has been formed (in the column on the right); and similarly the means for the separate months have been formed (in the bottom line), excluding those years in which the changes mentioned in the notes have been made.

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